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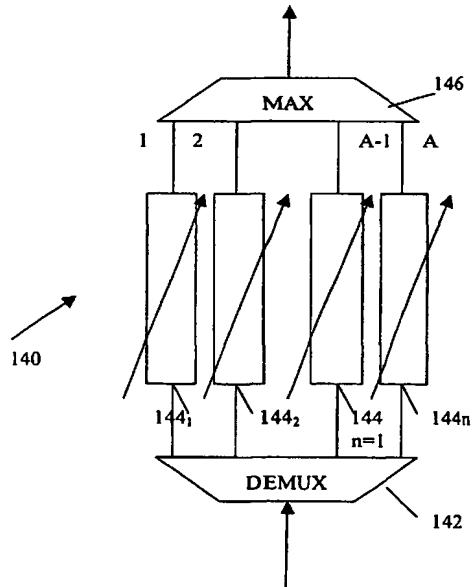
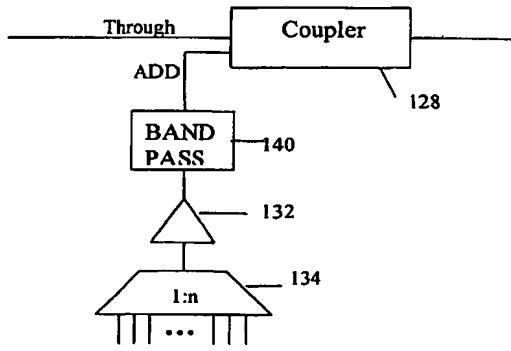
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(54) Title: NOISE REDUCTION IN OPTICAL COMMUNICATIONS NETWORKS



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(57) Abstract: The add path of a DWDM add/drop node comprises a n:1 coupler for combining n signal sources. The combined signal is amplified and then demultiplexed. Each output of the demultiplexer is passed through a variable optical attenuator (VOA) and the VOA outputs multiplexed to form the add signal. Channels carrying no add signal and not used to control the added signals are attenuated to zero to remove a broadband noise contribution from those channels. The signal sources are run at maximum power and the signal of those channels attenuated by the respective VOAs to control their amplitude and optimise the optical signal to noise ratio of the add signal.

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

## NOISE REDUCTION IN OPTICAL COMMUNICATIONS NETWORKS

This invention relates to the reduction of noise in optical communications networks, and in particular, to the reduction of noise in an add path where signals are placed onto the network at a network node.

5        Add/Drop multiplexers are widely used in optical communications networks to provide wavelength non-specific add/drop ports. This allows random transponder provisioning and tuneability. Figure 1 shows an example of how add/drop multiplexers are used. The optical network is a dual fibre DWDM optical network with one fibre 10 carrying traffic in an East/West direction and the other fibre 12 in a West/East direction.

10      The terms East and West are conveniently used to describe the direction in which network traffic travels and does not correspond to geographical East or West. The traffic is a multiplex, typically, of 32 wavelength channels. At network nodes, traffic is taken off the network and split into the component channels using an optical demultiplexer or a splitter and band pass filter and added into the network using an optical multiplexer and an add

15      coupler.

20      The network nodes can add or drop traffic to either of the network fibres. It is desirable to route traffic the shortest distance around the network which will depend on the location of the destination node. It is also desirable to have a fall back path should one of the E/W or W/E paths fail.

Thus, in Figure 1, each of the E/W and W/E network fibres comprise an amplification stage 14. This is a EDFA amplifier although this may be omitted in shorter networks. The applied signal is split in a 2:1 coupler 16 to provide two signal output paths. A through path 18 carries traffic that remains on the network and a drop path 20 drops the 5 signal multiplex from the network for processing at the network node.

Each of the two dropped paths are input to an optical demultiplexer 22 which splits the signal into its constituent wavelength components. The receive transponder includes a switch 24 to select the signal output from one of the two demultiplexers. In practice in a 32 10 channel node, this switch will receive 32 channels from each of the demultiplexers.

Signals remaining on the through path pass through a channel control unit 26 and then to an add coupler 28 in which signals from the transmit side of the node transponder are added onto the network. The output of the add coupler is finally amplified again at 30 if 15 required.

The add side of the transponder comprises an amplifier 32 and an n:1 add coupler 34, where n is the number of wavelengths in the multiplex carried by the network. The add coupler is required to add the individual wavelength signals that are to be placed onto the 20 network. Use of add couplers has the disadvantage of incurring losses and causing the add power level to require amplification. Thus, the add signal is amplified. This in turn causes broadband noise which passes into the system degrading the OSNR (optical signal to noise ratio) of the added signals as well as those signals passing through the photonic add/drop

node. It is known to add tuneable filters 36 following the add amplifier to remove the noise added to the through channels.

5 In the figure, the add coupler is shown as a multiplexer 34. Separate multiplexers may be used on the east and west paths.

The noise that is generated is dependant on the gain of the amplifier in the add path. This gain is determined by the maximum possible losses in the add path. When a signal is added, the source powers are adjusted on a per channel basis to achieve the required power 10 at the point of addition. The signal to noise ratio is therefore worst when the loss of the add path is less than the maximum loss possible. The OSNR is optimised when the path loss is a maximum as the noise from the EDFA amplifier experiences the maximum loss.

15 This situation is undesirable and the present invention seeks to overcome by improving or optimising the add channel OSNR.

In its broadest form the invention overcomes the problem by filtering out the EDFA noise on signal paths which have no add content and controlling the signal amplitude of the added signals after amplification.

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More specifically, there is provided an optical network node for an n channel DWDM optical network, the node comprising an add path for adding an n-channel wavelength multiplex onto the network, in which some of the n channels carry signals to be added onto the network, wherein the add path comprises an n-channel signal combiner

for combining the n signal channels, and optical amplifier for amplifying the output of the signal combiner, a multichannel wavelength selective filter with variable per channel loss for blocking channels not carrying signals to be added to the network or controlling the amplitude of the added signals, and an add coupler for coupling the add path to the 5 network.

The invention also provides a method of adding an n-channel DWDM signal to an n-channel DWDM network combining signals from a plurality of signal sources to provide an n-channel add signal output, amplifying the combined output, selectively blocking 10 wavelength channels of the combined signal not carrying signals to be added onto the network or controlling the amplitude of the added signal, and coupling the n-channel add signal onto the optical network.

In an embodiment of the invention, the wavelength selective filter attenuates 15 channels carrying signals to be added to the network to control their amplitude.

Preferably, the selective band pass filter comprises an n-channel demultiplexer having n outputs, an n channel multiplexer having n inputs and a variable optical attenuator arranged between each of the demultiplexer outputs and multiplexer inputs, wherein the 20 variable attenuator on any given channel is set to block the signal on that channel if no signal on that channel is to be added onto the network.

By demultiplexing the channels of the amplified output of the add signal combiner, a variable optical attenuator can be used on each channel selectively to filter out the

contribution of that channel to the broadband noise if that channel does not carry an add signal. This has the advantage that the broadband noise in the add path can be reduced.

Preferably, the add signal sources are run at full power and the respective VOAs are used to control the power of the signals in these channels.

5

This has the further advantage of further improving the OSNR of the add path signal.

10 Embodiments of the invention will now be described, by way of example only, and with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of a known add/drop node on an optical network described previously;

15 Figure 2 is a view of a portion of the node of Figure 1 modified to embody the invention;

Figure 3 is a more detailed view of the multiplexer/demultiplexer arrangement of Figure 2; and

20

Figure 4 is a view, similar to Figure 1 of an add/drop node embodying the invention.

The add path shown in Figure 2 comprises a 32:1 combiner 134 which combines the 32 signal channels to produce a single output signal which is amplified by amplifier 132 and then passed to a WDM multiplexer/demultiplexer device 140. This device is illustrated in more detail in Figure 3. The output of the device 140 forms the add input to 5 add coupler 128 on one of the E/W and W/E paths of the network.

Figure 3 shows the mux/demux device 140 in more detail. The device comprises an optical demultiplexer 142 which receives the multiple wavelength input signal and splits it into  $n$  single wavelength outputs. In this example,  $n=32$  and is the number of channels 10 supported by the network. Each of the 1 to  $n$  outputs of the demultiplexer 142 is passed through an individual variable optical attenuator (VOA) 144(1)....144( $n$ ). The outputs of the 32 variable optical attenuators form the 1 to 32 inputs to an optical multiplexer 146 which remultiplexes the 32 signal paths to output a DWDM multiplex to be added back onto the network by one of the add couplers 28.

15

Thus, the device 140 is a 2 port device which provides filtering around the channels but which also can adjust the through loss on a channel to channel basis.

20 Variable optical attenuators (VOAs) are well known and commonly used in optical networks. They can be used to match optical power levels and equalise the power between different DWDM channels, as well as for other applications. VOAs are used to equalise power levels in the output of multiplexers. In the embodiment of Figure 3, the multiplexer demultiplier and VOA array is used to block noise on channels that are not being added or used to control the added channels. The optical sources being added are run at maximum

power and their output amplitude controlled by the respective VOA 144 assigned to that channel. The worst case occurs when the add path losses are at a maximum which equates to the best OSNR achieved before use of the VOAs. As the add path losses fall, the device 140 introduces more attenuation to control the signal amplitude reaching the output. Thus 5 the signal amplitude remains the same but the EDFA noise experiences greater attenuation improves the OSNR of the added signal.

Figure 4 shows how the device of Figures 2 and 3 can be incorporated into the add drop node of Figure 1. It will be appreciated that a mux/demux device 140 is inserted into the 10 add path of each of the add paths to the E/W and W/E fibre paths. In Figure 4, the references of Figure 1 are incremented by 100 and the components are otherwise unchanged.

Various modifications to the embodiment described are possible and will occur to 15 those skilled in the art. The invention is not confined to any particular optical network type and may be used on ring or line networks with or without network amplification. Various devices are suitable for use as the optical multiplexer and demultiplexer and variable optical attenuators. The invention is limited only by the scope of the following claims.

CLAIMS

1. An optical network node for an  $n$  channel DWDM optical network, the node comprising an add path for adding an  $n$ -channel wavelength multiplex onto the network, in which some of the  $n$  channels carry signals to be added onto the network, wherein the add path comprises an  $n$ -channel signal combiner for combining the  $n$  signal channels, and optical amplifier for amplifying the output of the signal combiner, a multichannel wavelength selective filter with variable per channel attenuation for blocking channels not carrying signals to be added to the network or controlling the amplitude of the added signals, and an add coupler for coupling the add path to the network.
  
2. An optical network node according to claim 1; wherein the selective band pass filter comprises an  $n$ -channel demultiplexer having  $n$  outputs, an  $n$  channel multiplexer having  $n$  inputs and a variable optical attenuator arranged between each of the demultiplexer outputs and multiplexer inputs, wherein the variable attenuator on any given channel is set to block the signal on that channel if no signal on that channel is to be added onto the network and the channel is not used to control the amplitude of the added signals.
  
3. An optical network node according to any of claims 1 to 2, comprising means for running the sources of the  $n$ -channel signals at maximum power.
  
4. A DWDM optical communications network having a plurality of nodes according to any of claims 1 to 3.

5. A method of adding an n-channel DWDM signal to an n-channel DWDM network combining signals from a plurality of signal sources to provide an n-channel add signal output, amplifying the combined output, selectively blocking wavelength channels of the combined signal not carrying signals to be added onto the network or controlling the amplitude of the added signals, and coupling the n-channel add signal onto the optical network.

6. A method according to claim 5, comprising running the signal sources at full power to optimise the optical signal to noise ratio of the signal added to the network.

7. A method according to any of claims 5 or 6, comprising demultiplexing the combined amplified add signal using an n-channel demultiplexer, passing each of the output channels of the demultiplexer through a variable optical attenuator (VOA) and multiplexing the VOA outputs to form the network add signal.

8. A method according to claim 7, wherein the non-signal carrying channels are blocked by attenuating to zero the outputs from the demultiplexer corresponding to those channels.

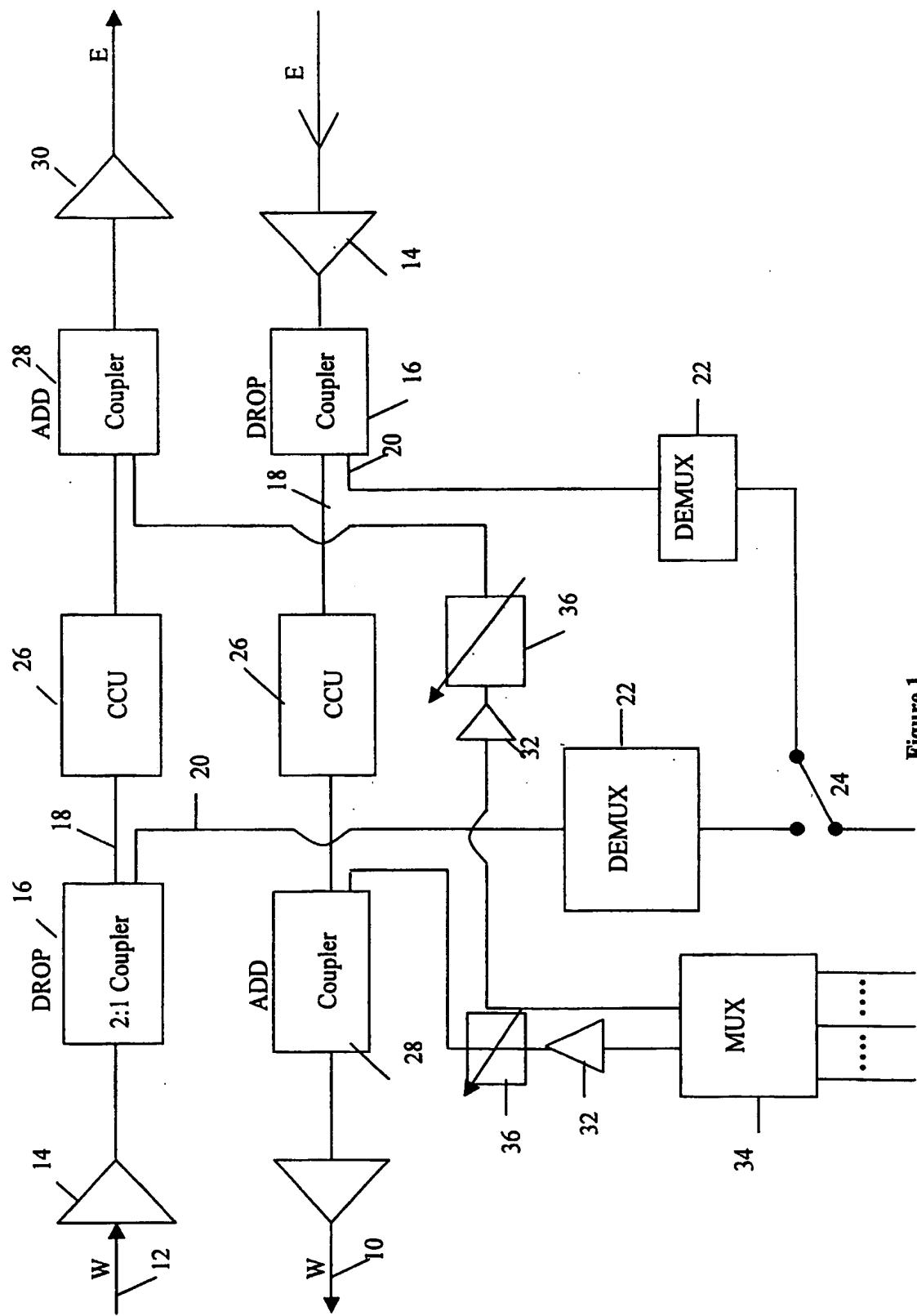
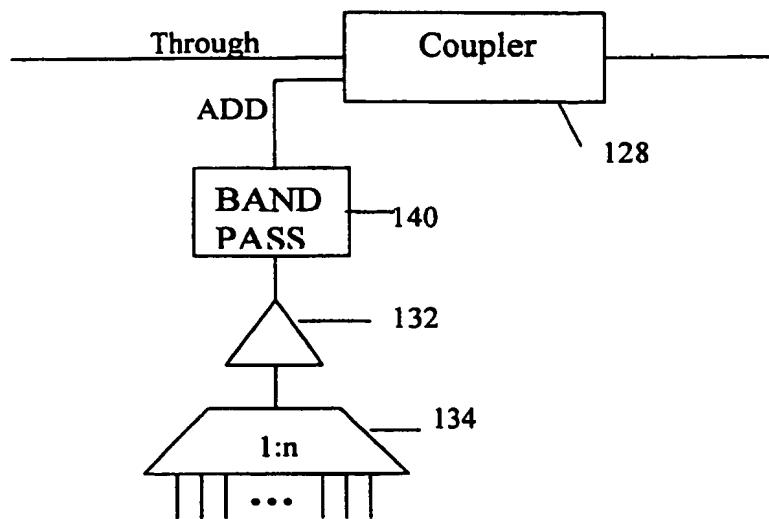
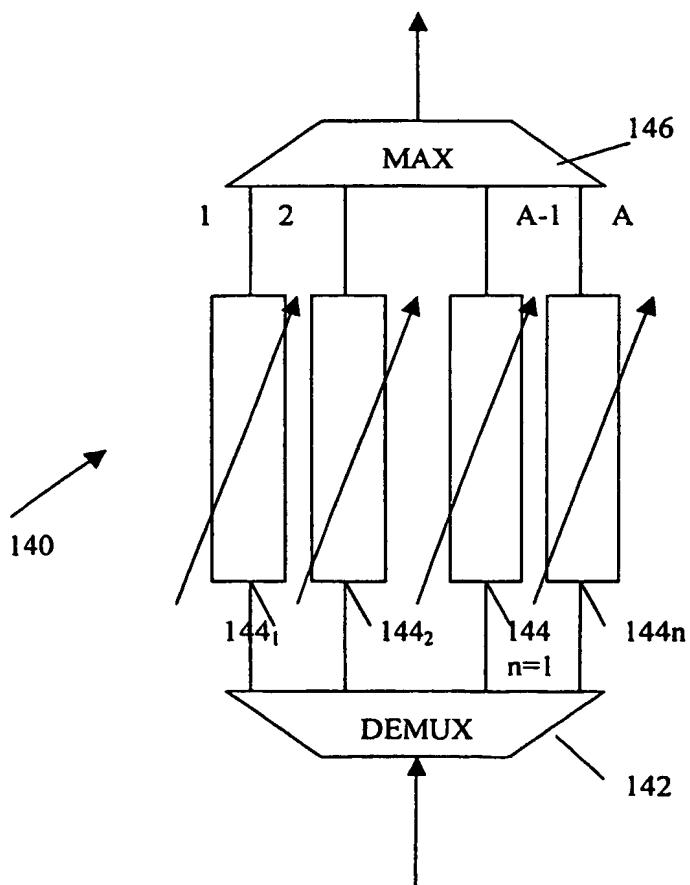


Figure 1

**Figure 2****Figure 3**

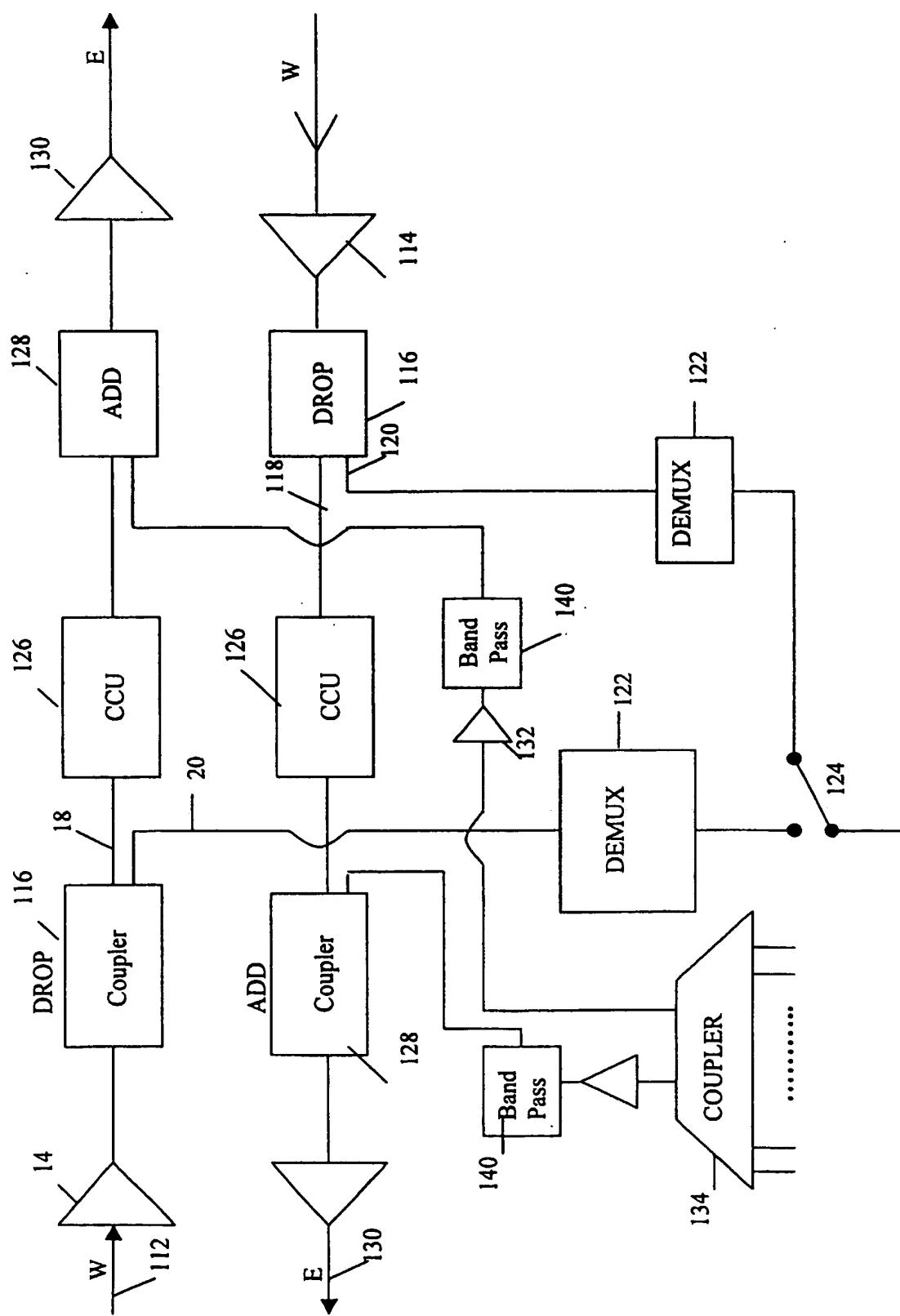


Figure 4

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## A. CLASSIFICATION OF SUBJECT MATTER

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According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H04J H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, EPO-Internal, PAJ, INSPEC, COMPENDEX

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 288 810 B1 (MELI FAUSTO ET AL) 11 September 2001 (2001-09-11) abstract column 1, line 5 - line 20 column 17, line 60 -column 20, line 34; figure 8 ---	1, 3-6
Y	EP 1 156 607 A (MARCONI COMM LTD) 21 November 2001 (2001-11-21) abstract column 5, line 50 - line 58 column 7, line 39 -column 8, line 11 ---	2, 7, 8
Y	---	2, 7, 8

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

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European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Chauvet, C

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national Application No  
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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 285 479 B1 (OKAZAKI KAZUE ET AL) 4 September 2001 (2001-09-04) abstract column 1, line 14 - line 18 column 7, line 25 - line 26 column 21, line 17 -column 23, line 9; figure 11 -----	1-8

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

National Application No

PCT/GB 02/05721

Patent document cited in search report	Publication date		Patent family member(s)		Publication date
US 6288810	B1	11-09-2001	IT MI961638 A1 AU 731543 B2 AU 3941497 A BR 9710612 A EP 1008239 A1 NZ 333360 A US 2002196495 A1 WO 9805133 A1 US 6437888 B1		02-02-1998 05-04-2001 20-02-1998 17-08-1999 14-06-2000 29-04-1999 26-12-2002 05-02-1998 20-08-2002
EP 1156607	A	21-11-2001	GB 2362525 A AU 4601701 A CN 1325203 A EP 1156607 A2 JP 2002044019 A NO 20012438 A US 2002015553 A1		21-11-2001 22-11-2001 05-12-2001 21-11-2001 08-02-2002 19-11-2001 07-02-2002
US 6285479	B1	04-09-2001	JP 11127461 A CN 1215268 A ,B US 2002030869 A1		11-05-1999 28-04-1999 14-03-2002